



**Biomass-Fired Cogeneration Project:
Best Available Control Technology
Analysis for Greenhouse Gases
Sierra Pacific Industries
Lumber Manufacturing Facility
Anderson, California**

Prepared for:
Sierra Pacific Industries, Inc.
Redding, California

Prepared by:
ENVIRON International Corporation
Lynnwood, Washington

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1 Introduction

Sierra Pacific Industries, Inc. (SPI) owns and operates an existing lumber manufacturing facility located in Anderson, California, and proposes to construct and operate a cogeneration unit at that facility. The boiler associated with the proposed cogeneration unit will be designed to burn biomass fuel to produce approximately 250,000 pounds of steam per hour. SPI submitted a PSD permit application to USEPA Region 9 and Shasta County Air Quality Management District (SCAQMD) in March 2010 that included BACT analyses for all criteria pollutants expected to increase by more than the PSD Significant Emission Rates (SERs), as well as pollutants exceeding the emission rate thresholds in SCAQMD Rule 2:1, Part 301. This report is intended to supplement that permit application by providing a BACT analysis for GHG emissions from the biomass-fired cogeneration unit.

On May 13, 2010, USEPA issued the final “Tailoring Rule” with a stated intent to establish a “common sense approach” to addressing greenhouse gas emissions from stationary sources, by “tailoring” the major source applicability thresholds under the PSD and Title V air operating permit programs. The first step of the Tailoring Rule, which began on January 2, 2011, and lasts until June 30, 2011, requires sources already subject to the PSD permitting programs to meet that program’s permitting requirements for greenhouse gases. New sources or modifications of existing sources expected to increase total greenhouse gas emission rates by 75,000 tpy or more, on a carbon dioxide equivalent (CO₂e) basis, and whose emissions exceed the PSD threshold for one or more criteria pollutants, are subject to PSD review for GHGs.

The second step of the rule, which starts on July 1, 2011, and lasts until June 30, 2013, casts a wider net than the first. New construction projects expected to emit at least 100,000 tpy of total greenhouse gases on a CO₂e basis, or modifications at existing facilities that are expected to increase total greenhouse gas emissions by at least 75,000 tpy CO₂e will be subject to PSD permitting requirements, even if they do not significantly increase emissions of any other pollutant. Because the proposed biomass-fired cogeneration unit is expected to emit GHGs at a rate greater than 75,000 tpy CO₂e, the project is subject to PSD review for GHGs. Because there are no ambient standards or increments for GHGs, the only PSD requirement that applies to GHGs is that Best Available Control Technology (BACT) must be employed to reduce GHG emissions from the proposed unit.

1.1 Project Information

SPI is a family-owned wood-products company based in Redding, California. SPI currently operates an existing lumber manufacturing facility in Anderson, California. SPI intends to construct a new cogeneration unit at the Anderson facility that would burn biomass fuels in a boiler to produce steam that would be used to generate electricity and to heat existing lumber dry kilns at the facility.

The cogeneration unit will consist of a biomass-fired water tube boiler with a step grate and dual-chamber pyrolysis and combustion system, a cooling tower, a steam turbine, and an electrical generator. The boiler will burn biomass fuels to produce high-pressure steam for the steam turbine. The steam turbine will drive the electrical generator, which will be capable of generating up to 31 megawatts (MW) of electricity, approximately 7 MW of which will be used to

power on-site equipment; the remainder will be sold to a public utility. Low-pressure steam will be taken from the steam turbine through a controlled extraction and used to heat the dry kilns.

1.2 BACT Analysis Process

BACT is defined at 40 CFR 52.21(b)(12) as:

an emissions limitation (including a visible emission standard) based on the maximum degree of reduction for each pollutant subject to regulation under the Clean Air Act which would be emitted from any proposed major stationary source or major modification which the Administrator, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes or available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of such pollutant. In no event shall application of best available control technology result in emissions of any pollutant which would exceed the emissions allowed by any applicable standard under 40 CFR Parts 60 and 61. If the Administrator determines that technological or economic limitations on the application of measurement methodology to a particular emissions unit would make the imposition of an emissions standard infeasible, a design, equipment, work practice, operational standard, or combination thereof, may be prescribed instead to satisfy the requirement for the application of best available control technology. Such standard shall, to the degree possible, set forth the emissions reduction achievable by implementation of such design, equipment, work practice or operation, and shall provide for compliance by means which achieve equivalent results.

The process for conducting BACT analyses for criteria pollutants is relatively well established because it has been implemented for decades. Although there is a wide range of controls and associated costs that could be considered for criteria air pollutants, permit-issuing agencies have an understanding of which emission control options are appropriate and cost effective. In contrast, BACT analyses, BACT determinations, and cost-effectiveness criteria for GHGs are virtually non-existent.

In November 2010, USEPA issued guidance for conducting BACT analyses for GHGs (hereafter referred to as “the November 2010 Guidance”). USEPA recommended (but did not require) that permitting agencies apply to GHGs the same “top down” process applied to determine criteria pollutant BACT. In this process, potentially available control technologies are identified and evaluated for application to the proposed project. Feasible options are ranked in descending order of control effectiveness. The most stringent alternative is examined and is established as BACT unless the applicant demonstrates and the permitting authority agrees that energy, environmental or economic impacts justify a conclusion that the most stringent technology is not achievable. In that case the next stringent alternative is considered. The top-down analysis process is comprised of the following steps:

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- **Step 1 – Identify Available Control Technologies.** Identify all available control techniques that could potentially be applied to control emissions of the regulated pollutants from the emission units.
- **Step 2 – Eliminate Technically Infeasible Alternatives.** If any of the control techniques cannot be successfully used on the emission units due to technical difficulties, document this finding. Such control techniques would not be considered further in the BACT analysis.
- **Step 3 – Rank Technically Feasible Alternatives.** Assess the performance of each control technique and rank them beginning with the most effective control technique.
- **Step 4 – Evaluate Economic, Energy, and Environmental Impacts.** Estimate emission reductions, annual costs, cost effectiveness, energy impacts, and other environmental impacts of the controls techniques. Detailed cost effectiveness information is presented for the most effective control and for other control techniques that are in the least cost envelope.
- **Step 5 – Select BACT.** Identify the most effective option not rejected based on energy, environmental, and economic impacts.

Each step is discussed further in the sections that follow.

1.2.1 Step 1 – Identify Available Control Technologies

The first step in the top-down procedure is to identify all available control technologies and emission reduction options for each subject pollutant. Available control technologies are those with a practical potential for application to the emission unit. For criteria pollutants, applicants typically identify appropriate control technologies by reviewing the following sources of information:

- USEPA RACT/BACT/LAER Clearinghouse (RBLC)
- USEPA Control Technology Center (CTC)
- Recent Permit Actions by other State and Local Agencies, and
- Vendor Information

Because BACT for GHGs is a new requirement, there are very few BACT precedents, let alone precedents for a biomass-fired cogeneration unit. In preparing this BACT analysis, ENVIRON reviewed BACT analyses for a combined cycle power plant in the San Francisco Bay area (Russell City), a proposed combination refinery and integrated gasification combined cycle (IGCC) facility in South Dakota (Hyperion Energy Center), and a biomass-fired cogeneration facility adjacent to a paper mill in Wisconsin (We Energies/Domtar Biomass Energy Project). The We/Domtar Biomass Energy Project BACT analysis demonstrated that good boiler design and combustion practices were BACT for control of GHGs from the biomass-fired boiler.

Consistent with these precedents and EPA's November 2010 Guidance, this analysis demonstrates that the design of the proposed biomass-fired cogeneration unit will achieve a very high degree of energy efficiency. In BACT parlance, this is considered "lower-polluting processes/practices" as opposed to post-combustion or "end-of-stack" controls. Given the limited technological options available for end-of-stack GHG emission controls, EPA's initial BACT guidance emphasizes energy efficiency. In addition to reducing GHG emissions, energy efficiency also minimizes criteria and toxic air pollutant emissions.

A control technology must be "available" to be considered BACT. According to EPA's draft 1990 NSR manual "[a]vailable" means that the method's systems and techniques are commercially available." BACT also does not require the applicant to participate in a research and development project to determine if a technology is "available" for a particular use.

Theoretical, experimental or developing technologies are not "available" under BACT. Technologies with questionable or dubious reliability are likewise not considered "available" under BACT, and the applicant is not required to use them. BACT does not require an applicant to speculate as to whether an undemonstrated technology will effectively control the pollutant in question from the proposed source. Applicants are not required to accept the risk that a theoretically feasible, but unproven, technology will effectively and economically reduce emissions from the proposed source.

1.2.2 Step 2 – Eliminate Technically Infeasible Control Technologies

The second step in performing the top-down BACT analysis is to eliminate all technically infeasible options. The determination that a control technology is technically infeasible is source-specific and based upon physical, chemical, and engineering principles. Technical feasibility is addressed in EPA's November 2010 Guidance:

EPA considers a technology to be technically feasible if it has been demonstrated in practice or is available and applicable to the source type under review. The term "demonstrated" is focused on the technology being used in the same type of source, such as a similar plant producing the same product. Therefore, EPA considers a technology to be "demonstrated," if it has been installed and operated successfully on the type of source at issue.

Prior guidance and judicial decisions confirm that "feasible technology" means design or equipment that has progressed beyond the conceptual and pilot testing phases, is commercially available, and has been demonstrated on a full-scale emission unit of the type of that is the subject of the BACT analysis, for a period of time sufficient to indicate reliable operation. These criteria are especially important for GHG BACT analyses due to the unproven nature of many GHG control schemes.

"Demonstrated in practice" is another important concept that addresses the question of whether a technology should be considered available. In its New Source Review Improvement Rule (issued November 22, 2002), EPA included a definition of "demonstrated in practice." This definition prescribes which technologies must be considered in BACT and LAER determinations by defining the information that must be reviewed to identify candidate technologies, the amount

of time the technology must be in use, and its performance during that time. A technology installed and operating on an emissions unit (or units) must meet the following criteria to be considered “demonstrated in practice:”

- Has operated at a minimum of 50 percent of design capacity for at least 6 months; and
- The pollution control efficiency performance has been verified by either:
 - 1) a performance test, or
 - 2) performance data collected at the maximum design capacity of the emissions unit (or units) being controlled, or 90 percent or more of the control technology's designed specifications.

Although this definition of “demonstrated in practice” does not have any regulatory standing in the analysis presented in this report, it does provide some useful guidance for evaluating whether certain technologies are “available,” and therefore worthy of consideration as BACT.

1.2.3 Step 3 – Rank Remaining Control Technologies by Control Effectiveness

The third step in the top-down BACT analysis is to rank all remaining control technologies with respect to control effectiveness (i.e., by emission limit or removal efficiency, as applicable). The emission limit or removal efficiency used in the ranking process is that which the technology has demonstrated can be achieved consistently under reasonably foreseeable worst-case conditions with an adequate margin of safety. A limit or removal efficiency that can be achieved only occasionally under best-case circumstances is not to be considered.

For GHGs, control options are ranked based on total CO₂e rather than the total mass or mass of individual GHGs.

1.2.4 Step 4 – Evaluate Most Effective Controls and Document Results

In this step, an analysis is performed on each remaining control technology to determine whether the energy, economic, or environmental impacts from a given technology outweigh their benefits. Factors such as control efficiency, anticipated emission rate, expected emissions reduction, and economic, environmental, and energy impacts, are to be considered.

If the top-ranked technology is chosen, and there are no significant or unusual environmental impacts associated with that technology that have the potential to affect its selection, the BACT analysis is complete, and no further analysis is required. However, if the chosen technology is not the top-ranked option, the economic, environmental, and energy impacts of the chosen technology, and each more-effective technology, must be evaluated and compared to justify application of the selected technology.

In performing economic analyses, USEPA's Air Pollution Control Cost Manual, published in January 2002 (EPA/452/B-02-001) provides capital and annual operating cost factors that can be used in determining the installation and operating costs of each control technology. Actual vendor installation and operation costs were used where applicable.

Cost-effectiveness evaluations for greenhouse gases are to be conducted based on reductions in CO₂e. However, as acknowledged by EPA in its November 2010 Guidance, no cost effectiveness criteria have been established for GHGs. Furthermore, there are no means by which to evaluate the environmental impacts of GHG emissions at the stationary source level. Consequently, comparisons of environmental impacts associated with GHG emissions with those of collateral criteria pollutant emissions are not possible.

1.2.5 Step 5 – Select BACT

The final step is selection of the most stringent and technically feasible emission limit and corresponding technology that was not eliminated based upon adverse economic, environmental, and energy impacts. EPA's November 2010 Guidance notes that a GHG permit may limit CO₂e based on a mass emission rate (lb/hr) or other metrics. EPA also notes that "since the environmental concern with greenhouse gases is with their cumulative impact in the environment, metrics should focus on longer-term averages (e.g., 30- or 365-day rolling average) rather than short-term averages (e.g., 3- or 24-hr rolling average)."

Although this process might appear to be tightly prescribed, 20 years of experience with the top-down BACT analysis process has resulted in a number of agency and judicial decisions that have served to guide subsequent BACT determinations:

- BACT determinations are made "on a case-by-case basis," taking into account site-specific and source-specific characteristics. These characteristics may include, among other things, the type of fuel or raw materials that will be used, and the type and size of the emissions unit. A high degree of technical judgment must be exercised in any BACT analysis as there are various sizes and ages of the emissions units covered by an analysis.
- BACT must be achievable. The Environmental Appeals Board (EAB) has recently stated that, while BACT is forward-looking, "the word 'achievable'...constrains the permit issuer's discretion by prohibiting BACT limits that would require pollution reductions greater than what can be achieved with available methods." The EAB concluded that "the permit issuer may take into account the absence of long-term data, or the unproven long-term effectiveness of the technology, in setting the emissions limitation that is BACT for the facility." The EAB further stated that the BACT analysis "must be solidly grounded on what is presently known about the selected technology's effectiveness," and that "emissions limitations achieved by other facilities, and corresponding control technologies used at other facilities are an important source of information in determining" BACT.

EPA's November 2010 Guidance affirms that vendor confidence in emission control efficiency should be considered: "[t]he willingness of vendors to guarantee a certain level of performance should be considered by the permitting authority later in the BACT process when proposing a specific emissions limit or level of performance in the PSD permit."

Finally, the chosen BACT emission limit must not be less stringent than any applicable federal NSPS, NESHAP, or state-specific emission standard. It should be noted, however, that there

are no federal NSPS, NESHAP, or California State GHG emission standards that apply to biomass-fired cogeneration units.

1.3 Cost-Effectiveness Analysis

In Step 4 of the top-down BACT analysis process, cost effectiveness is used to assess the economic impact of emission reduction alternatives. The cost effectiveness of a control option is defined as dollars per ton (\$/ton) of pollutant removed or avoided when compared with some baseline (usually the uncontrolled emission rate), and is calculated as follows:

$$\frac{\text{Total Annualized Costs of Control Option}}{(\text{Baseline Annual Emissions} - \text{Control Option Annual Emissions})}$$

In cases where more than one control option is being considered, an incremental cost effectiveness is often calculated, as follows, to determine the cost per ton of the additional quantity of pollutant reduced at some additional expense:

$$\frac{(\text{Total Annualized Costs of Control Option} - \text{Total Annualized Costs of Next Control Option})}{(\text{Control Option Annual Emissions} - \text{Next Control Option Annual Emissions})}$$

1.3.1 Cost Methodology

The total annualized cost of each control is calculated as follows:

- i) Total Annual Costs = Annualized Capital Costs + Annual Operations & Maintenance Costs
- ii) Annualized Capital Costs = Capital Recovery Factor x Total Direct and Indirect Capital Costs

Where:

$$\text{Capital Recovery Factor (CRF)} = \frac{i(1+i)^n}{((1+i)^n - 1)}$$

and, assuming:

$$\text{Life of Equipment, } n = 20 \text{ years}$$

$$\text{Annual Interest Rate, } i = 7\%$$

$$\text{CRF} = 0.094393$$

1.3.2 Cost Criteria

Step 4 of the BACT process addresses economic, energy, and environmental impacts associated with feasible control options. The economic evaluation enables an applicant an opportunity to demonstrate that the costs of pollutant removal for a particular control option are disproportionately high. However, EPA's November 2010 Guidance acknowledges "there is not a wealth of GHG cost effectiveness data from prior permitting actions for a permitting authority to review and rely upon when determining what cost level is considered acceptable for GHG

BACT.” EPA also acknowledges that cost effectiveness criteria historically applied to criteria pollutant emissions are not appropriate for greenhouse gases because greenhouse gas emissions tend to be orders of magnitude greater than criteria pollutant emissions. In fact, we find that at this early stage of greenhouse gas BACT review, there is virtually no information that enables applicants or reviewing agencies to determine whether a control option is cost effective.

An Interim Report issued in February 2010 by the Climate Change Work Group of the Permits, New Source Review and Toxics Subcommittee to the EPA’s Clean Air Act Advisory Committee, which includes industry, environmental, and regulatory groups, provided no consensus on greenhouse gas cost effectiveness, with values ranging from \$3 per ton to \$150 per ton. Some members supported not setting fixed cost effectiveness thresholds, and recommended that EPA provide guidance to permitting authorities on the range of cost effectiveness values based on the status of various control technologies.

An obvious source of carbon cost information is the value of carbon allowances or offsets. Analogous to EPA’s acid rain program, an allowance is an authorization under a regulatory program to emit a certain quantity of carbon. However, a carbon offset is an emission reduction established outside of a regulatory program, and may or may not be recognized by a regulatory program.

The Regional Greenhouse Gas Initiative (RGGI, <http://www.rggi.org>) is the first mandatory, market-based effort in the United States to reduce greenhouse gas emissions. Ten Northeastern and Mid-Atlantic states have implemented a CO₂ cap, effective until 2014, after which the cap will be reduced by 2.5 percent each year until a total reduction of 10 percent is achieved by 2018. States sell nearly all emission allowances through auctions and invest the proceeds in consumer benefits such as energy efficiency, renewable energy, and other clean energy technologies.

At a RGGI auction held March 9, 2011, allowances averaged \$1.89 per ton of CO₂. “Future” allowances also averaged \$1.89 per ton, implying that the value of CO₂ allowances is not expected to change significantly in the near future. Eighty-five percent of the allowances available at the auction were purchased by electric utilities and affiliates.

RGGI-participating states currently allow regulated power plants to use a carefully-chosen group of qualifying offsets to meet up to 3.3 percent of their CO₂ compliance obligation. Examples of offset-eligible project categories include those that capture or destroy methane from landfills or through agricultural manure management operations.

Similar in nature to RGGI allowances, European Union Allowance units (EUAs) are sold in Europe as a mechanism for achieving an EU objective of a 20 percent reduction in carbon emissions by 2020 (compared to 1990 levels). The price of an EUA in April 2011 was approximately 16 euros (equivalent to about \$23) per metric tonne.

The Chicago Climate Exchange (CCX) was a voluntary, legally binding, GHG reduction and trading system until it closed in November 2010. At that time, the price of carbon credits (which

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had not traded on the CCX since February 2010) ranged between \$0.05 and \$0.10 per metric tonne of CO₂e.

When developing the GHG Tailoring Rule, EPA used scaling to derive a Significant Emission Rate for greenhouse gases from the Significant Emission Rates for criteria pollutants. Applying a similar rationale, one could derive a greenhouse gas cost effectiveness criterion by scaling CO₂ emissions from CO emissions. Using a relatively conservative cost effectiveness criterion of \$10,000/ton, and emission factors for external natural gas combustion from EPA's AP-42 emission factor database (84 and 120,000 lb/scf for CO and CO₂, respectively), a comparable cost-effectiveness criterion for CO₂ would be \$7/ton (i.e., \$10,000 x 84 / 120,000).

In October 2010, Hyperion Energy Center (a proposed combination oil refinery and integrated gasification combined-cycle power plant) submitted a greenhouse gas BACT analysis to South Dakota Department of Environment and Natural Resources in support of a renewal of a previously issued PSD permit that calculated the cost effectiveness of implementing Carbon Capture and Storage (CCS) on a CO₂ vent, refinery process heaters, and combined cycle gas turbines. The calculated cost effectiveness of the various control options ranged from \$43 to \$124 per ton of CO₂e. Absent any established cost effectiveness criteria, the Hyperion BACT analysis cited the Chicago Climate Exchange offset prices (less than \$1 per ton at the time) and the EU allowance prices (\$12 per tonne at the time) and concluded that CCS was not cost effective. South Dakota has not yet renewed the PSD permit for the Hyperion facility, and a contested case hearing is scheduled for July 25, 2011.

We Energies provided a GHG BACT analysis in support of a permit application submitted to Wisconsin Department of Natural Resources proposing to install and operate a biomass-fired boiler. The GHG BACT analysis included cost-effectiveness calculations for systems to control methane (CH₄) and nitrous oxide (N₂O), but did not provide any cost-effectiveness criteria for comparison.

Lacking specific guidance from EPA or local agencies, and weighting several sources that imply values less than \$2/ton against an EU Allowance of \$23/tonne, SPI proposes a GHG cost-effectiveness threshold of \$7/ton, derived by scaling the commonly-accepted cost-effectiveness threshold for criteria pollutants (\$10,000/ton) using natural gas combustion emission factors.

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2 Project Greenhouse Gas Emissions

The Tailoring Rule defined GHGs as an aggregate of: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). The proposed project has the potential to emit only three of these: CO₂, CH₄, and N₂O. All GHG emissions associated with the project will be generated by the cogeneration unit; the cooling tower will not emit any GHGs. The Tailoring Rule further defined CO₂e as the sum of the mass emissions of the constituent GHG, each multiplied by the appropriate global warming potential (GWP) factor provided in Table A-1 of the Federal Mandatory GHG Reporting Rule (MRR, codified in 40 CFR Part 98).

The proposed cogeneration unit is assumed to have an annual average heat input of 425 million British thermal units per hour (MMBtu/hr). Table 2-1 summarizes the calculations and shows that the proposed unit has the potential to generate a maximum of approximately 393,000 tons of CO₂e per year. The proposed unit combusts a small amount of natural gas during a limited number of startup events throughout the year, but the vast majority of emissions will be from combustion of wood and wood-residual solid biomass fuel. Additionally, the CO₂ emission factor for natural gas combustion provided in the MRR is 117 lb/MMBtu, so any accounting for natural gas combustion would reduce the maximum potential GHG emission rate.

Table 2-1. Greenhouse Gas Energy Output Emission Factor Calculations

Pollutant	Emission Factor (Heat Input) ¹		Global Warming Potential ²	Emission Rate ³	
	(kg/MMBtu)	(lb/MMBtu)		(lb/hr)	(tpy)
CO ₂	93.8	207	1	87,973	385,322
CH ₄	3.20E-02	0.0705	21	30.0	131
N ₂ O	4.20E-03	0.00926	310	3.94	17
CO ₂ e	--	--	--	89,824	393,431

1 The kg/MMBtu emission factors for combustion of wood and wood residual solid biomass fuel are from 40 CFR Part 98, Tables C-1 and C-2; the lb/MMBtu emission factors are calculated by converting the kg/MMBtu emission factors using 2.2046 lb/kg.

2 100-year time horizon global warming potential (GWP – from 40 CFR Part 98, Table A-1.

3 Calculated by multiplying the emission factor by the annual average heat input (425 MMBtu/hr). CO₂e was calculated by multiplying each individual emission rate by the applicable GWP factor, and summing.

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3 Step 1 – Identify Available Control Alternatives

The first step of a top-down BACT analysis is to identify all available pollutant reduction options. Options typically fall into three categories: inherently low-emitting processes, clean fuels, and add-on control technologies. While step 1 is intended to include all possibilities, there are limits to the scope of the first two option categories (i.e., inherently low-emitting processes and clean fuels). The list of options in step 1 need not include those that fundamentally redefine the nature of the proposed source or modification.

Considerable argument and litigation has been generated over what constitutes “redefinition of the source.” The most recent approach outlined by the Environmental Appeals Board (EAB) is contained in a 2009 ruling to remand a permit issued to Desert Rock Energy Co., LLC. In that ruling, which referred extensively to a previous ruling (Prairie State Generation Co., LLC), the EAB says that the reviewing agency should seek to answer the question: “when does the imposition of control technology require enough of a redesign of the proposed facility that it strays over the dividing line to become an impermissible redefinition of the source?”

In response to its own question, the EAB stated that “the permit applicant initially defines the proposed facility’s end, object, aim, or purpose – that is the facility’s basic design, although the applicant’s definition must be for reasons independent of air permitting.” Furthermore, the permit issuer should “take a ‘hard look’ at the application determination in order to discern which design elements are inherent for the applicant’s purpose and which design elements may be changed to achieve pollutant emissions reductions without disrupting the applicant’s basic business purpose for the proposed facility, while keeping in mind that BACT, in most cases, should not be applied to regulate the applicant’s purpose or objective for the proposed facility.”

In the November 2010 Guidance document, USEPA acknowledges that, although “clean fuels” are to be considered in step 1 of the BACT analysis, the initial list of control options does not need to include “clean fuel” options that that would fundamentally redefine the source. In this case, use of the biomass fuel generated by the existing facility is part of the original motivation for the project. Clearly, substitution of any other fuel, lower-carbon-containing or otherwise, would drastically alter the overall goals of the proposed project.

3.1 Carbon Dioxide

Carbon dioxide (CO₂) is a by-product of complete combustion. Altering the combustion process to reduce CO₂ emissions would increase emissions of “traditional” air pollutants such as carbon monoxide (CO) and volatile organic compounds (VOCs). Maximizing the heat transfer efficiency of the boiler and the mechanical efficiency of the steam turbine and generator minimizes the quantity of fuel combusted, and therefore the quantity of CO₂ generated, per unit of steam or electricity generated. Add-on technologies that are able to remove, or “capture,” CO₂ from the post-combustion exhaust stream have been developed. Following capture, the CO₂ would be transported and stored permanently, or “sequestered,” in a geologic formation. Such systems, referred to as “carbon capture and sequestration” (CCS), are not yet commercially available, and the U.S. Department of Energy does not expect them to be available until approximately 2025.

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In March 2011, USEPA issued “Guidance for Determining Best Available Control Technology for Reducing Carbon Dioxide Emissions from Bioenergy Production” (hereafter referred to as the “March 2011 Guidance”) which states that, if the proposed emission unit “can demonstrate that utilizing a particular type of biogenic fuel is fundamental to the primary purpose of the project,” then “the options listed as Step 1 of a top-down BACT analysis of GHGs may be limited to (1) utilization of biomass fuel alone, (2) energy efficiency improvements, and (3) carbon capture and sequestration.”

3.2 Methane

Like carbon monoxide (CO) and volatile organic compounds (VOCs), methane (CH₄) emissions are generally the result of incomplete fuel combustion. In the case of biomass, volatile compounds (including CH₄) are released as the fuel is heated in the furnace, some portion of which escapes combustion by improper mixing with oxygen or being confined to zones of relatively low temperature.

Proper combustion practices and use of a properly designed boiler maximizes complete combustion, which minimizes formation of CH₄. Add-on controls used to remove CH₄ from gas streams include activated carbon adsorption systems and thermal or catalytic oxidation systems. Adsorption systems pass the gas stream through canisters filled with activated carbon, and the CH₄ is trapped in pores located on the carbon particles. When the carbon approaches saturation, the canister is replaced and processed to remove the CH₄, which is recovered or destroyed. Oxidation systems increase the temperature of the gas stream until the CH₄ oxidizes, forming CO₂ and water. Thermal oxidizers destroy CH₄ using a flame, while catalytic oxidation uses a catalyst to promote the oxidation reaction at a temperature lower than the combustion temperature of CH₄.

3.3 Nitrous Oxide

Unlike nitric oxide (NO), which is the product of high combustion temperatures (greater than 730 °C or 1,350 °F), nitrous oxide (N₂O) is the result of lower combustion temperatures (less than 800 °C or 1,475 °F). Its formation can be limited to some extent by using proper combustion techniques and a properly designed boiler that promotes uniform furnace temperatures. Typically, furnace conditions that favor CH₄ formation, also favor N₂O formation.

Add-on controls to reduce N₂O emissions include: non-selective catalytic reduction (NSCR), thermal destruction, and catalytic destruction. In the 1970s, NSCR systems were widely used to control N₂O (and NO_x) emissions from adipic and nitric acid production operations, but high energy costs reduced the popularity of this approach. Currently, NSCR systems have been used to reduce emissions from reciprocating engines operated in a rich-burn or stoichiometric mode. In general, NSCR systems pass the exhaust gases over catalysts, which use metals (e.g., platinum, rhodium, palladium) to convert NO_x, CO, and VOCs to water, nitrogen, and carbon dioxide. Unburned hydrocarbons in the exhaust are used as a reducing agent to enable one catalyst to convert N₂O and NO_x, while CO and VOCs are oxidized by another catalyst. In cases where the option to consistently operate in a fuel-rich or stoichiometric mode to provide the reducing agent is not available, natural gas can be injected to act as the reducing agent.

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Thermal destruction of N_2O is achieved using a reducing flame burner combusting premixed methane or natural gas. The flame temperature must be maintained high enough to destroy the N_2O , but below $1,500\text{ }^{\circ}\text{C}$ to minimize NO_x formation. Catalytic destruction is accomplished at lower temperatures (400 to $700\text{ }^{\circ}\text{C}$) using metal- or zeolite-based N_2O -decomposing catalysts.

Conventional commercially-available selective catalytic reduction (SCR) systems (i.e., those using titanium, tungsten, and vanadium-based catalysts) used to reduce emissions of nitric oxide (NO) and nitrogen dioxide (NO_2), as well as selective non-catalytic reduction (SNCR) systems, generate N_2O , so removal of such control systems would reduce N_2O emissions. However, at least two companies (BASF and Heraeus) have developed catalysts designed to simultaneously remove both N_2O as well as NO and NO_2 .

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4 Step 2 – Eliminate Technically Infeasible Alternatives

In the second step of a top-down BACT analysis, the available pollutant reduction options listed in Step 1 are considered, and, if found to be technically infeasible for the specific emission unit under review, eliminated.

4.1 Carbon Dioxide

In Step 1, use of biomass fuel, energy efficiency, and CCS were identified as potential control technologies.

Biomass Fuel

Combustion of biomass fuels, alone or in combination with other fuels, in boilers to generate steam is a long-standing practice. Biomass is one of the original boiler fuels, and it remains a feasible and often-used fuel.

Energy Efficiency

Maximizing the quantity of steam or electricity generated per unit of fuel combusted is the goal of most boiler designers and operators. Striving for energy efficiency is technically feasible within the limitations of the second law of thermodynamics. At maximum operation, the efficiency of the proposed boiler (i.e., the fraction of the energy in the fuel that is transferred to the steam) is expected to be approximately 70 percent. The efficiency of the electrical generator is, at full load, approximately 96 percent. The overall efficiency of the cogeneration unit will vary depending upon the quantities of steam used to heat the kilns and generate electricity, but is expected to vary between 37 and 53 percent.

Carbon Capture and Sequestration

In its findings and recommendations report, issued on January 24, 2011, the California Carbon Capture and Storage Review Panel concluded, among other things, that the technology “for the safe and effective capture, transport, and geological storage of CO₂ from power plants and other large industrial facilities” currently exists. Therefore, CCS is considered to be technically feasible.

There are three approaches to CO₂ capture that are generally applicable to power generation:

- Pre-combustion systems designed to separate CO₂ and hydrogen (H₂) from produced syngas,
- Post-combustion systems designed to separate CO₂ from flue gas, and
- Oxy-combustion that uses high-purity oxygen (O₂) instead of air, which produces flue gas composed largely of CO₂.

Of these, only post-combustion systems will be considered for application to a biomass-fired boiler. Use of a pre-combustion system would require a gasification unit to produce syngas

from the biomass fuel, which would amount to redefining the source. Oxy-combustion of biomass fuels is currently in the experimental phase, and is typically in the context of being co-fired with coal.

4.2 Methane

In Step 1, proper combustion, thermal oxidation, and catalytic oxidation were identified as possible alternatives for CH₄ reduction.

Proper Combustion

For boilers combusting biomass, proper combustion is a ubiquitous control technology used to reduce CO and hydrocarbon (including CH₄) emissions, therefore it is considered technically feasible for control of CH₄ emissions.

Thermal Destruction

To thermally oxidize a pollutant in an exhaust stream, a combustor is located in the exhaust duct, and fuel (typically natural gas) and enough supplemental air to support a flame are introduced. While the thermal oxidizer may destroy CH₄ in the exhaust, the combustor itself will generate a certain quantity of air pollutants, including CH₄. Because a thermal oxidizer has never been used to reduce CH₄ emissions from a biomass-fired boiler, and it is not clear that use of such a system would result in a net reduction in CH₄ in the exhaust stream, this technology is considered technically infeasible for reducing CH₄ emissions from a biomass-fired boiler.

Catalytic Destruction

When applied to boilers, the intent of a catalytic oxidation system is to reduce CO and, to a lesser extent, VOC and PM emissions. As discussed in the criteria pollutant BACT analysis submitted with the PSD permit application, while catalytic oxidation is not experimental, application to biomass-fired boilers is uncommon and difficult. Regardless of whether the catalyst is located upstream of downstream of a particulate control device (e.g., an electrostatic precipitator), alkali compounds in the exhaust gas deactivate the catalyst. To counteract the deactivation, large quantities of catalyst must be deployed and frequently replaced, resulting in unpredictable boiler availability and control system costs. Nevertheless, application of a catalytic oxidation system to reduce CH₄ emissions from a biomass-fired boiler is technically feasible.

4.3 Nitrous Oxide

In Step 1, proper combustion, thermal destruction, catalytic destruction, NSCR, removal of SCR systems, and addition of N₂O-abating SCR systems were identified as possible alternatives for N₂O reduction.

Proper Combustion

For boilers combusting biomass, proper combustion is a ubiquitous control technology used to reduce CO and hydrocarbon emissions, therefore it is considered technically feasible for control of N₂O emissions.

Thermal Destruction

To thermally oxidize a pollutant in an exhaust stream, a combustor is located in the exhaust duct, and fuel (typically natural gas) and enough supplemental air to support a flame are introduced. While the thermal oxidizer may destroy N₂O in the exhaust, the combustor itself will generate a certain quantity of air pollutants, including N₂O. Because a thermal oxidizer has never been used to reduce N₂O emissions from a biomass-fired boiler, and it is not clear that use of such a system would result in a net reduction in N₂O in the exhaust stream, this technology is considered technically infeasible for reducing N₂O emissions from a biomass-fired boiler.

Catalytic Destruction

When applied to boilers, the intent of a catalytic oxidation system is to reduce CO and, to a lesser extent, VOC and PM emissions. As discussed in the criteria pollutant BACT analysis submitted with the PSD permit application, while catalytic oxidation is not experimental, application to biomass-fired boilers is uncommon and difficult. Regardless of whether the catalyst is located upstream of downstream of a particulate control device (e.g., an electrostatic precipitator), alkali compounds present in the exhaust gas deactivate the catalyst. To counteract the deactivation, large quantities of catalyst must be deployed and frequently replaced, resulting in unpredictable boiler availability and control system costs. Nevertheless, application of a catalytic oxidation system to reduce N₂O emissions from a biomass-fired boiler is technically feasible.

Non-Selective Catalytic Reduction Systems

NSCR systems have primarily been developed to reduce N₂O emissions from adipic and nitric acid production operations. There are no instances of an NSCR system being applied to reduce N₂O emissions from a biomass-fired boiler. Because significant differences exist between the exhaust from adipic and nitric acid operations and that of a biomass-fired boiler, it is not clear that the technology could be transferred effectively, and is therefore considered not technically feasible for control of N₂O from biomass-fired boilers.

Removal of Selective Non-Catalytic Reduction Systems

An SNCR system is proposed by SPI to reduce NO_x emissions from the biomass-fired boiler. It is technically feasible to not install such a system.

Removal of Conventional Selective Catalytic Reduction Systems

SPI does not propose to install a conventional SCR system to reduce NO_x emissions from the biomass-fired boiler. The criteria pollutant BACT analysis provided with the PSD permit application indicated that SCR was technically feasible, but had a still-unproven track record of reliable performance associated with biomass-fired boilers. Since no SCR system is proposed for installation on the biomass-fired boiler, it is technically infeasible to not install such a system.

Addition of N₂O-Abating Selective Catalytic Reduction Systems

The criteria pollutant BACT analysis provided with the PSD permit application concluded that conventional SCR systems were technically feasible for reducing NO_x emissions from biomass-fired boiler; therefore, N₂O-abating SCR systems are also considered technically feasible.

5 Step 3 – Rank Technically Feasible Alternatives

In Step 3, the remaining alternatives that have not been removed from consideration due to technical infeasibility, are ranked, starting with the most effective. The November 2010 Guidance says that “to best reflect the impact on the environment, the ranking of control options should be based on the total CO₂e rather than the total mass or mass for the individual GHGs. Before ranking all feasible control alternatives from the previous section are ranked together, the effectiveness of each on a CO₂e basis is discussed.

Proper Combustion/Energy Efficiency

The proposed project would operate in a manner that minimizes emissions of all pollutants, and maximizes the energy derived from the fuel consumed. Thus, these measures, in combination, are considered the baseline from which all other alternatives will be evaluated, and it is assumed that all other options would be applied in addition to these measures.

Biomass Fuel

The proposed boiler will be fired exclusively using biomass fuel, and SPI expects approximately 75 percent of that fuel to be comprised of sawmill residues from the Anderson sawmill and the nearby Shasta Lake sawmill. The remaining 25 percent is expected to be a combination of in-forest residues, agricultural residues from orchards in the Sacramento Valley, and urban wood residues diverted from landfills. Efficiently combusting mill residues, in-forest residues, and agricultural residues to generate steam and electricity results in less net GHG emissions (i.e., less CH₄ and N₂O are generated) than if those same residues were allowed to decompose or be subject to open burning. In the March 2011 Guidance, EPA acknowledges that the combustion of lumber manufacturing residues to generate energy does not increase net atmospheric GHG stock.

Furthermore, SPI manages nearly 1.7 million acres of forest land in California using sustainable forestry practices, and most of the carbon in the wood harvested from those forest lands remains sequestered in produced lumber. SPI replants harvested areas within a year, and plants an average of 6 million seedlings each year. The combined effect of: (1) younger trees taking up more carbon than harvested mature trees, (2) the sequestration of carbon in produced lumber, and (3) the most-effective conversion of residues to CO₂ by combustion in the proposed boiler is that SPI's operations serve to reduce atmospheric CO₂ stocks.

Carbon Capture and Sequestration

A CCS system is comprised of three parts: (1) capturing the CO₂, (2) transporting the CO₂, and (3) permanently storing the CO₂. The effectiveness of the system to reduce CO₂ emissions is determined by the removal rate of CO₂ from the flue gas, and degree to which the CO₂ is retained while being transported and stored. Currently available technology can capture approximately 90 percent of the post-combustion CO₂ in flue gas. However, due to the considerable energy requirements for the capture and compression of the CO₂, the electrical generating capacity of the proposed cogeneration unit would have to be increased by up to 40

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percent. Although 90 percent of the additional CO₂ generated would also be captured, the net CO₂ reduction would be reduced from 90 percent to 86 percent.

Transport of CO₂ by pipeline is a mature technology, and expected losses of CO₂ in a pipeline would be minimal. Experimental observations and models suggest that properly selected and maintained geological storage sites could trap over 99 percent of injected CO₂ for at least 100, and up to 1 million, years.

A CCS system would have no impact on CH₄ or N₂O in the exhaust; the increase in emissions of those GHG compounds as a result of the additional capacity needed to power the CCS systems would further degrade the net GHG reduction. On a CO₂e basis, CCS has the potential to reduce GHG emissions by approximately 83 percent.

Catalytic Destruction

Catalysts are a notoriously ineffective means of destroying CH₄ at typical exhaust temperatures (i.e., less than 700 °C), and the low availability of oxygen in combustion exhaust would further degrade the effectiveness. At best, a 20 percent reduction in CH₄ emissions has been documented when applied to internal combustion engines.

When applied to exhaust from an adipic acid operation, catalytic destruction systems are effective, reducing N₂O emissions by up to 95 percent. Although it is unclear that the same reductions would be realized when similar catalysts are applied to a biomass-fired boiler, the stated levels of control will be assumed valid. Catalysts would have no effect on CO₂ in the exhaust. Applying these catalysts together would result in a potential GHG emission reduction of, at most, 1.4 percent on a CO₂e basis.

Non-Selective Catalytic Reduction

Applied to a nitric acid production operation, NSCR systems can achieve a 90 percent reduction in N₂O emissions. An NSCR system would not affect CO₂ or CH₄ concentrations in the exhaust. Assuming that an NSCR system could achieve a similar reduction in N₂O emissions when applied to a biomass-fired boiler, the GHG emission reduction would be 1.2 percent on a CO₂e basis.

Removal of NO_x Control System (SNCR)

SNCR systems convert, depending upon the reagent and furnace conditions, between 10 and 20 percent of NO_x in the exhaust to N₂O. SNCR systems do not generate any CO₂ or CH₄, so elimination of the system would not affect concentrations of these compounds in the exhaust gas. Assuming the SNCR system accounts for all of the N₂O generated by the boiler, and that removal of the SNCR system would reduce N₂O emissions to zero, the reduction in GHG emissions would be 1.4 percent on a CO₂e basis.

Ranking GHG Control Alternatives by Effectiveness

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Below is a ranking of the technically feasible GHG control alternatives, starting with the most effective, on a CO₂e basis:

- Biomass Fuel – Net reduction in atmospheric CO₂ stocks
- Carbon Capture and Sequestration – 83 percent reduction in emitted GHGs on a CO₂e basis
- Catalytic Destruction – 1.4 percent reduction in emitted GHGs on a CO₂e basis
- Removal of NO_x Control System (SNCR) – 1.4 percent reduction in emitted GHGs on a CO₂e basis
- Non-Selective Catalytic Reduction – 1.2 percent reduction in emitted GHGs on a CO₂e basis
- Proper Combustion/Energy Efficiency – Baseline

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6 Step 4 – Evaluate Economic, Energy, and Environmental Impacts

In the March 2011 Guidance, EPA suggests that, instead of the more traditional approach where the options are considered and either eliminated or adopted in order of effectiveness, the economic, energy, and environmental impacts of all options are considered. In light of this guidance, each technically feasible option was evaluated, regardless of the Step 3 ranking.

Biomass Fuel

Over 75 percent of the fuel combusted in the proposed boiler is expected to be derived from residues generated by SPI's primary business (i.e., harvesting logs and manufacturing lumber). Use of this fuel provides an economic benefit by allowing SPI to avoid the cost of purchasing fuel to heat the on-site lumber dry kilns, purchasing electricity to power the facility, and to generate revenue by the sale of excess electricity. Similarly, an energy benefit is derived by combusting a renewable fuel instead of a fossil fuel to generate steam.

The March 2010 Guidance states that “a case-by-case analysis of the net atmospheric impact of biomass fuels would likely be prohibitively time-consuming and complex for facilities and permitting authorities.” In lieu of such an analysis, the net environmental benefit described in Step 3 is realized through the combination of converting virtually all of the carbon in the fuel to CO₂, replanting harvested forest land with saplings, and sequestering the majority of the carbon harvested from forest land in produced lumber. Because of the positive economic, energy, and environmental impacts of burning biomass fuel in lieu of fossil fuels, this alternative is considered BACT for GHG emissions from the proposed boiler.

Carbon Capture and Sequestration

As discussed in Step 3, CCS systems require additional energy to remove CO₂ from the boiler flue gas, as well as to compress it for transport and storage. In the case of a biomass boiler, the concentration of CO₂ in the exhaust gas is relatively dilute (i.e., between 15 and 20 percent by weight), which would require a strong solvent to capture the CO₂, as well as a considerable amount of energy to regenerate the solvent. The economic impacts of this additional energy requirement would be in addition to the capital and operating costs associated with equipping and maintaining a CCS system.

Most cost information related to CCS technology focuses on fossil fuel (particularly coal) combustion, natural gas processing, and syngas production operations. U.S. Department of Energy analyses indicate that application of post-combustion CCS technology to a new 550 MWe net output coal-fired power plant would cost approximately \$86 per ton of CO₂ avoided. This is over ten times the cost-effectiveness threshold of \$7 per ton proposed in Section 1.3.2, even without accounting for the economy of scale realized by a 550 MWe unit as compared to that of a 31 MWe unit.

The considerable monetary and energy requirements of a CCS system suggest unacceptable economic, energy, and environmental impacts. The increased energy requirements would result in additional emissions of all pollutants other than CO₂, and, therefore, CCS systems have

an unacceptable collateral environmental impact as well. As a result, CCS systems are removed from consideration as BACT for GHGs emitted by the proposed boiler.

Catalytic Destruction/Non-Selective Catalytic Reduction

Because these alternatives reduce emissions of GHGs other than CO₂, they are each estimated to reduce GHG emissions, on a CO₂e basis, by less than 6,000 tons per year. In order to be considered cost effective, and assuming the cost-effectiveness threshold of \$7 per ton proposed in Section 1.3.2, the annual cost of each system would have to be less than \$42,000 annually, which is unlikely, based on the costs of catalytic systems used to reduce criteria pollutants. The economic analysis provided in the criteria pollutant BACT analysis for a catalytic oxidation system to reduce CO and VOC emissions indicated that the economic impact of these systems, due to uncertainties regarding the reliability and cost of the systems, would be unacceptable. Because the GHG reduction associated with these systems (on a percent basis) is less than the expected reduction in CO and VOC associated with an oxidation catalyst system, and the cost-effectiveness threshold for GHGs is lower than what is typical for CO and VOC, these alternatives are considered to have unacceptably high collateral economic impacts, and are removed from consideration as BACT for GHG emissions from the proposed boiler.

Removal of NO_x Control System (SNCR)

Elimination of the SNCR system used to reduce NO_x emissions from the boiler would result in an increase in NO_x emissions. Because the criteria pollutant BACT analysis associated with the submitted PSD permit application proposed SNCR as BACT for NO_x emissions from the boiler, elimination of the SNCR system would result in unacceptable NO_x emissions from the boiler, and is therefore not an acceptable alternative for GHG BACT based on unacceptable collateral environmental impacts, and are removed from consideration as BACT for GHG emissions from the proposed boiler.

Proper Combustion/Energy Efficiency

Utilizing an efficient boiler design, and then operating the boiler to produce the most steam and electricity per unit of fuel combusted are control alternatives that SPI proposes to incorporate in the project. As stated previously, these options are considered the baseline for the BACT analysis, and all other options were considered to be applied over and above these two. These alternatives have a positive energy and environmental, and most likely economic, impact, and are considered to be BACT for GHG emissions from the proposed boiler.

7 Step 5 – Selection of BACT

Based on the analysis presented here, SPI proposes that BACT for GHGs from biomass-fired boilers is the exclusive use of biomass fuel (aside from natural gas use during startup and for flame stabilization), energy-efficient system design, and proper combustion practices. Because a variable fraction of the generated steam will be used to heat the lumber dry kilns, a single output-based BACT limit is impractical. For steam generation, SPI proposes a rolling 12-month average GHG emissions limit of 2,500 pounds of CO₂e per megawatt-hour (lb/MWh) of gross output. “Gross output” is defined as in 40 CFR Part 60, Subpart Db:

The gross useful work performed by the steam generated. For units generating only electricity, the gross useful work performed is the gross electrical output from the turbine/generator set. For cogeneration units, the gross useful work performed is the gross electrical or mechanical output plus 75 percent of the useful thermal output measured relative to ISO conditions that is not used to generate additional electrical or mechanical output or to enhance the performance of the unit (i.e. , steam delivered to an industrial process).

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